POINT TO POINT

TELECOMMUNICATIONS

A JOURNAL FOR THE TELECOMMUNICATIONS ENGINEER

VOLUME TWO · NUMBER ONE · OCTOBER 1957

Two shillings and sixpence

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Volume Two Number One October 1957

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Published by the Communications Division

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ENGLAND

Points of view

THE RELIABILITY OF RADIO EQUIPMENT is a subject which is certain to provoke discussion. In the past it has been accepted that the valves used in radio equipment were not susceptible to the same long term reliability as is obtained from cable and other types of telephone system. Consequently, one of the most important points which has had to receive attention in the design of multichannel equipment for telephone service (particularly those types involving unattended repeaters) has been valve life, and hence the overall reliability which can be obtained. Some telephone administrations have in the past been chary of embarking on the wide scale use of radio equipment because they felt that there was some risk of poor reliability, and therefore it is of interest to examine the performance of a particular system installed to test, among other things, this particular feature. It is obvious that to obtain results of this kind is a long drawn out process, since much time must elapse before any reliable information can be obtained.

A trial system of multichannel equipment was installed between the Marconi Works at Chelmsford and a site at Woolwich in 1949. This system comprised two terminals and two unattended repeaters and carried 12 channels for 24 hours each day. The repeaters were not necessary from a propagation viewpoint but were included to permit an overall check of a typical system.

Until the system was dismantled recently it was checked daily, but no adjustments were made unless the system failed to meet the specification. The system was commissioned with a new set of valves on the 4th June 1949 and they were replaced on the 9th March 1953. A log was kept of the replacements which were made in the meantime, and the Table lists the average recorded lives for the various types of valve used in the system.

Valve Type	*Total No. used in Link*	*FAILURES*		*Average Life of Valves (hrs)*	*Remarks*
		Total No.	*Average Life (hrs)*		
EF.91	138	3	28 000	31 900	—
EB.91	4	—	—	32 600	—
EAC.91	2	—	—	32 600	—
CV.131	2	—	—	32 600	—
ECC.91	6	4	9 250	19 560	—
QVO4/7	4	—	—	32 600	—
TT.15	6	9	10 800	13 040	—
KT.66	12	—	—	32 600	—
U.52	16	32	6 060	8 090	*Alternative types were used during the trial.*
5U4G	16	9	4 600	5 000	
ECC.32	8	1	26 500	29 000	—
829.B	6	—	—	25 680	*Still serviceable when removed from service. Replaced by experimental type.*

These results illustrate that the most unsatisfactory valve is the low power rectifier (Types U.52 or 5U4G). Even this valve, however, has an average life of the order of 5 000 hours (i.e. some six months of continuous service). This weakness is naturally receiving considerable attention and it is hoped that longer-life rectifiers will become available. However, because of this tendency it is becoming the practice to fit selenium rectifiers which have an anticipated life of 40 000 hours under tropical conditions.

Apart from the high degree of reliability achieved on this system due to long valve life, it was also found that circuit adjustment or maintenance was rarely necessary and the system operated for several months at a time without even minor adjustments being made. On one occasion the system operated for eleven months day and night without any of the equipment being touched.

This experience on one type of radio equipment indicates that a change of attitude towards maintenance can be adopted with advantage. It has

been customary to regard preventive maintenance as a good thing in itself, and the periodic replacement of valves as the best means of obtaining overall reliability in service. This experience suggests that it is better to limit maintenance to inspection and only to make changes or adjustments to the system when it can be seen that gradual deterioration will result in failure to meet the specification prior to the next visit. In particular it has shown up most clearly that it is preferable (except possibly in the case of rectifiers) to leave valves in service until they fail in the normal course of events rather than to adopt periodical changes of valves.

Automatic Power Plant for Telecommunications Installations

K. J. BLADON*

The development of radio equipment, particularly for multi-channel telephone service, capable of unattended operation for long periods has resulted in the development of power supply equipment of comparable reliability. This article discusses certain of the factors that have to be considered in power plant of this kind.

1 GENERAL

THE DEVELOPMENT of communications systems using radio links has led to extensive installations in territories in which reliable electrical power distribution systems are non-existent. This development in the communications field has, therefore, given rise to a demand for a reliable alternative source of electrical energy, and already automatic diesel power plants have proved their value in fulfilling this role.

These developments have given rise to the need for three basic types of diesel power plants, namely

(i) Dual installations

(ii) Mains standby installation

(iii) No-break installations.

The no-break installations do not fall within the scope of this article, but the dual and standby installations are dealt with in some detail in the following pages.

Power plant for this service can, of course, cover a large range of capacity. The particular application being discussed is generally applied

* Pelapone Engines Limited

to multichannel radio systems in the VHF, UHF and SHF bands, and for these the power requirements are small. A power demand of from 3-10 kW is the usual requirement.

Radio equipment has reached the stage of reliability such that inspection and routine adjustment in the absence of breakdown is only infrequently required. It is desirable that the power plant should also require the minimum routine attention.

2 THE DUAL DIESEL-ALTERNATOR INSTALLATION

It is usual to provide standby radio equipment and it is equally necessary to provide standby power plant. Thus the normal arrangement in the absence of mains power is for two diesel-alternators to be provided together with an associated control cubicle.

It is accepted practice to limit the running time of an individual diesel-alternator set to a set period. This can be as little as 48 hours or as long as 360 hours. Where the station is visited regularly, therefore, the duty equipment can be changed periodically by hand. Automatic changeover in the event of a fault is necessary, so the changeover between mains and standby equipments can also take place automatically. In hot and humid climates a short duty cycle is to be preferred, as in this way the electrical circuits are regularly operated.

A more recent development on dual installations is the introduction of automatic synchronizing at a changeover from one set to the other, either when due to a fault on the duty set or at the expiry of its duty cycle. Synchronizing will not, of course, be possible on the occurrence of all faults but to a large degree, its introduction into the dual installation does eliminate the break in installation power output. An installation so equipped also has push-button synchronizing controls to permit manual synchronizing for testing and changeover purposes. Electrical and mechanical interlocks are in any case usual for both synchronized and unsynchronized installations, to avoid accidental parallel connection of the alternators.

The sequence at changeover is thus the starting and running up to speed of the idle set, followed by the transfer of the load from the outgoing to the incoming set. This involves an interruption in the supply of

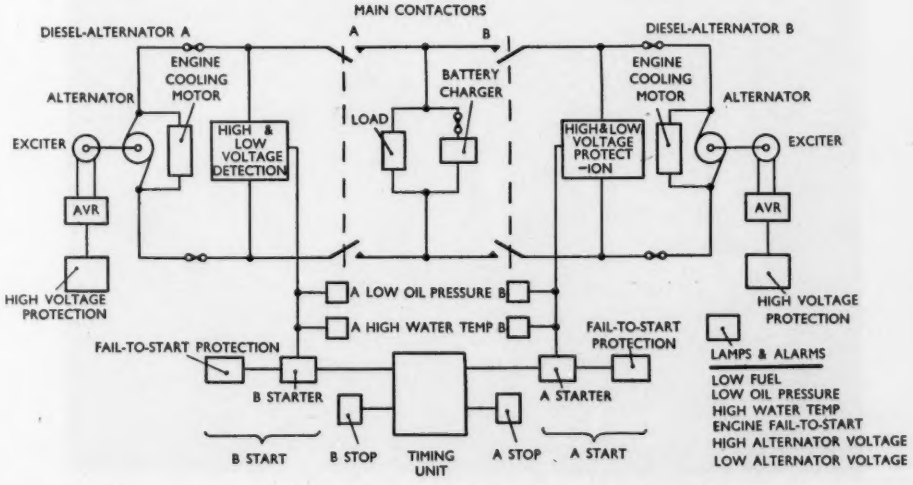
approximately 300 milliseconds, a break which is acceptable in many instances. The development of a fault on the set supplying power will automatically initiate such a changeover sequence when the fault is not of a major kind.

2.1 FACTORS AFFECTING THE PRIME MOVER

The prime mover in a diesel-alternator combination must operate reliably over long periods of time. Minor overhauls should not be required at intervals of less than six months, an operating period of some 2 500 hours. For this reason, running speeds below 1 000 RPM are usual for the small engines used for this class of service.

The majority of installations have hitherto employed water-cooled engines but more recent developments in air-cooled diesel engines have introduced these into the automatic power plant field.

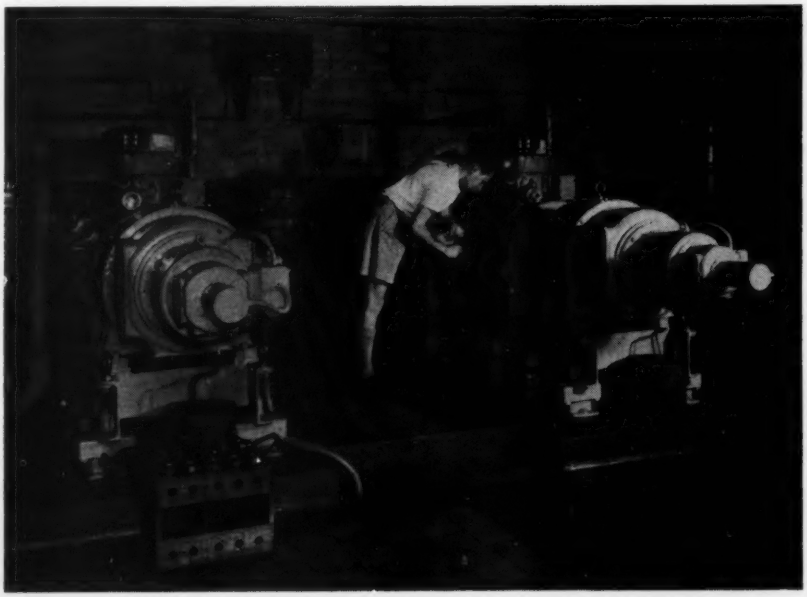
The chief disadvantage in the air-cooled engine is precisely where its chief advantage would appear to be, that is, in the absence of a water cooling system for, although the air-cooled engine does relieve the user



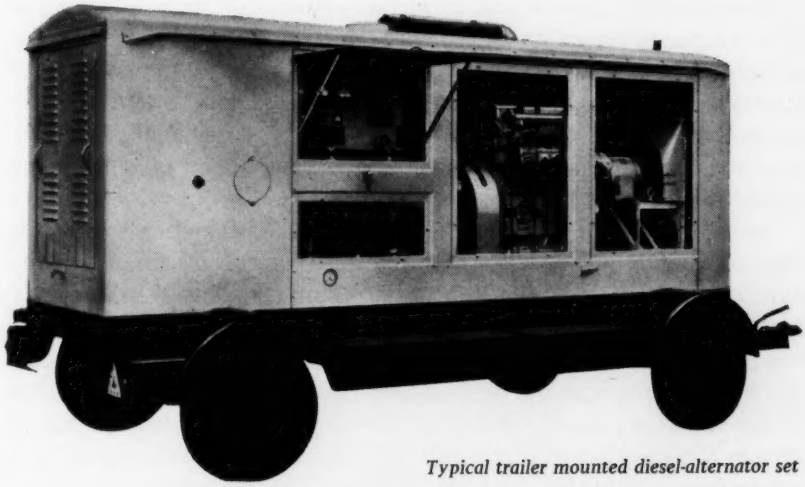
Block schematic diagram of dual diesel-alternator installation

of the need to provide and maintain a cooling water supply, it also removes the means by which the engine temperature can be maintained at a reasonable level at all times. On water cooled engines this is achieved by immersion heaters in the cooling systems or the use of a common system for both engines. This is in fact one of the most important requirements for a diesel-alternator installation, enabling the engine to be quickly started, taking over full load immediately.

The water is cooled either by an engine-mounted radiator, or by a separate electrically driven fan-cooled radiator. With the engine-mounted radiator the problem of adequate engine room ventilation, especially in climates where high temperatures occur, can become acute. It may be overcome by ducting from the radiator to an outlet opening in the engine



Typical dual diesel-alternator installation



Typical trailer mounted diesel-alternator set

room wall. A non-return flap louvre in the ducting ensures that the opening is sealed when the engine is not in operation.

When a separate radiator is used, the fan is driven by a motor fed from the alternator output, and the radiator situated at the engine room ventilation opening, avoiding the use of ducting from the radiator. As a cooling method it is slightly more expensive than the orthodox engine mounted radiator, and an allowance for the consumption of the fan motor must be made when computing the alternator rating.

The major point requiring attention on the engine, apart from the replenishment of the various supplies, is the fuel injection system. Both direct and indirect injection may be used. Over a period, the multiplicity of small holes necessary in direct injectors are more prone to blocking due to carbon formation than is the case with the single, larger, hole used with indirect injection, where the necessary atomization is obtained by the design of the pre-combustion chamber. (This condition can be aggravated if the set is insufficiently loaded, and ballast loads should be used to improve the load figure, despite the increase in fuel consumption.)

Close attention must be paid to the lubrication of all parts of the engine if the long-term reliability and the necessary low rates of wear are to be achieved. The engines used for this service are basically the same as for attended service and therefore additional filter capacity is necessary, together with means for the replenishment of the oil supply. A wall-mounted make-up tank is arranged to feed the lubricating system and the supply is controlled by float operated level switches on each engine.

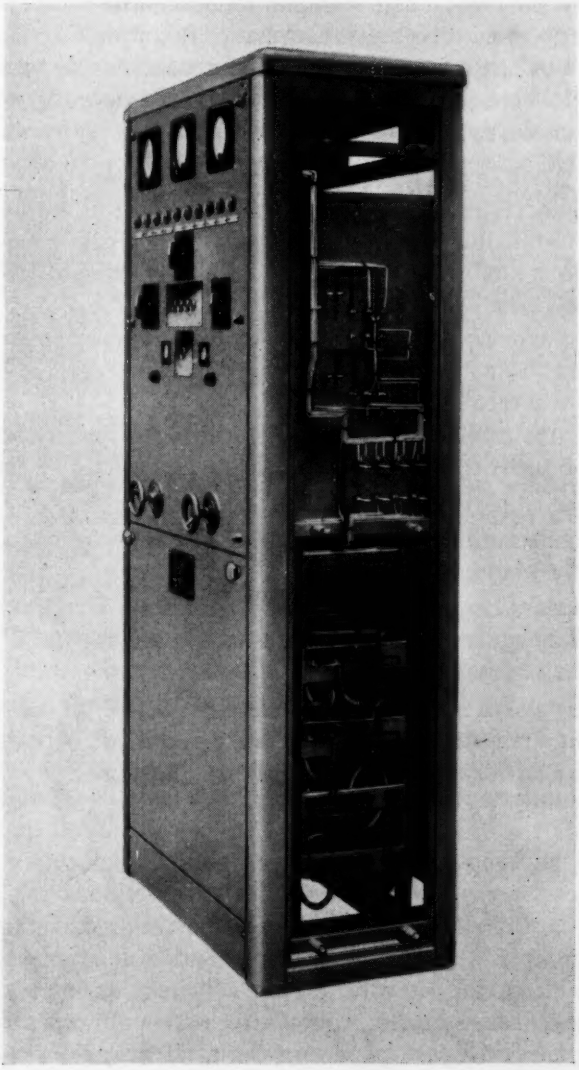
Some 'wet' sump lubricated engines utilize level switches mounted separately, in which case the oil in circulation may be limited to the normal sump capacity, being topped up from time to time by the make-up tank. There is some advantage in using a subsidiary tank on the engine baseplate, the oil in this tank being in circulation with the normal sump oil. With this arrangement the feed level switch is generally incorporated in the subsidiary tank. With 'dry' sump engines, the lubricating oil system is always separate from the engine and the lubricating oil tank can be increased in size to cover the running period required.

An installation comprising a dual set may share a common fuel service and fuel storage system and consequently a common refuelling arrangement.

The fuel service tank, wall mounted inside the engine room to give gravity feed to the engine injection system, has a capacity of from 24-48 hours running. The bulk storage tank situated outside the engine room may be buried, or in an outbuilding, and has sufficient capacity to maintain the installation in operation for the total period between visits, plus a suitable reserve.

For automatic refuelling the service tank contains a level switch operating on a float principle, with contacts arranged to close at the low and open at a predetermined high level. This switch operates the fuel transfer pump feeding the service tank from the bulk storage. The service tank, in addition to the fuel transfer switches, usually contains a low level switch arranged to close at a level below that at which the fuel transfer pump should have started and so detect any failure in the refuelling system.

An additional water header tank, wall mounted and connected into the engine radiator or cooler ensures that an adequate supply of cooling



Control cubicle for dual automatic diesel-alternator installation

water is available on a long running installation. The header tank contains a float operated valve and is automatically topped up from a water storage tank of larger capacity, wall mounted, and situated above the header tank. A separate header tank for each radiator fed by a common storage tank is the normal arrangement.

2.2 FACTORS AFFECTING THE ALTERNATOR

Both separately regulated and self-regulating alternators are suitable for the type of installation we are considering. Where separate regulation is used the exciter is small and usually forms an integral part of the machine. This arrangement is to be preferred as the use of multiple Vee-belt drives is avoided. Either static or vibrating regulators may be used and provided adequate protection against dust is made, there is little to choose between them.

Self-regulated machines are available utilizing various techniques of regulation. Broadly speaking, these can be divided into three classes:

(i) Those employing an Amplidyne principle.

(ii) Machines utilizing a portion of the AC output for self-excitation and regulation.

(iii) Machines employing a system of regulation which utilizes the shift of the armature magnetic neutral axis of the DC system under load.

The latter type of machine is not generally suitable for use with high quality communications equipment, being sensitive to power factor variation and having a waveform inferior to other types.

3 MAINS-STANDBY INSTALLATIONS

Where existing supply of mains power exists, supplementary facilities are only necessary when it is unreliable or widely varying. In these circumstances a single diesel-alternator set may be used as standby. The set functions only when the main supply is outside acceptable limits, usually confined to the detection of a low voltage condition on the distribution system, but where the frequency regulation of the supply system is likely to affect the performance of the communications equipment, out-of-limits detection may also be considered necessary for this para-

meter. On the restoration of the mains supply to within predetermined limits, the standby set will be automatically disconnected from the load, the mains supply reconnected and the standby set shut down. This cycle of events is automatically repeated at each mains failure condition. It will be seen, therefore, that with this type of installation, a definite break in the supply to the load will occur on mains failure. This break is determined by the time taken for the diesel-alternator set to run up to speed and attain its correct voltage.

It is general practice to run the standby set at a moderately high speed, and 1 500 RPM for a 50 cycle standby installation has become usual, since the set will normally operate only infrequently.

On restoration of the supply there will also be a break of about 300 milliseconds due to the contactors used to switch the supplies, but this is unimportant in view of the long interruption which takes place on failure of the primary supply.

If the set itself develops a fault, it will, of course, be shut down immediately. Faults against which sets are normally required to be protected are dealt with later.

4 CONTROL FACILITIES

The two diesel-alternator sets are controlled from a single unit as shown in Fig.1. This unit incorporates the timing devices, relays and contactors for changeover and fault protection.

Basically, the system operates automatically, each set completing a predetermined duty cycle, unless fault conditions intervene.

The following automatic fault protection features are essential for any diesel engine installation:

(i) Low lubricating oil pressure
(ii) High cooling water temperature
(iii) Failure to start.

In the case of air-cooled diesel engines, a 'High cylinder temperature' protection will be necessary.

On the occurrence of faults (1) and (2) on a dual installation, it is common practice to maintain the set in operation for a pre-set period following the detection of the fault. This short period is to enable the

second set to start up and take over the load, thus reducing the break in installation output. If the second set fails to take over within the pre-set period, the faulty set is immediately shut down. On a mains-standby installation it is not necessary to include the 'run on' feature and shut-down should occur immediately upon detection of the fault.

A 'failure-to-start' fault will result in the engine starter being disconnected from the battery after a pre-set period. This protects the starter which is short-time rated and also protects the starter battery from which the DC control circuits are fed and upon which the entire operation of the diesel plant equipment depends. In the event of this fault occurring

The Power Plant may be located away from the radio equipment, near a road, when access to the site is difficult. Connection can be by overhead low voltage cable. (Idanre, Nigeria)

on the incoming set of a dual installation, the duty set will continue to operate. A fourth protection, against engine overspeed, may have to be considered in certain instances, as in the event of a fault on some engine speed governors, the engine will 'race'. The overspeed protection may be effected by means of a centrifugal switch arranged to close at about 15 per cent engine overspeed. This protection does not entail a great deal of expense, as a centrifugal switch will normally be fitted to the engine to disengage the starter after the engine has fired. The occurrence of the engine overspeed fault should result in immediate shutting down of the set.

Protection can be provided against certain alternator faults. These may require an automatic shut-down or the set may be allowed to continue in operation for a short while. A high voltage fault, generally accepted as a voltage above 110 per cent of the nominal voltage, may damage the equipment comprising the load and, therefore, should result in the alternator being immediately disconnected. This fault is generally in the regulator circuit, and depending upon the method of regulation used, it may be possible to take the regulator out of operation automatically, and insert a fixed resistor into the exciter field. This fixed resistor will be set originally to a value determined by the installation load, so that on being inserted into the exciter field circuit, the alternator voltage will be reduced to a safe value. It must be borne in mind that the alternator is now controlled only by its inherent regulation, and providing the load is reasonably stable at the value for which the inserted exciter field resistor has been fixed, the alternator can be allowed to continue supplying the load. This is allowable on a mains-standby installation, but on a dual installation the alternator can be allowed to supply the load at the new voltage only until the second set takes over. When it is not possible to reduce the alternator voltage on the occurrence of the high voltage fault, an immediate shutting down of the set, whether in a dual or standby installation, should be automatic.

On the occurrence of a low voltage condition on a dual installation the set normally continues to supply the load until the second set has started up and an automatic changeover effected. This will only be possible, of course, if the voltage-out-of-limits condition has not reduced

the voltage to a major extent. On a mains-standby installation it is general practice to shut the set down automatically on the occurrence of the fault.

In any AC power system, attention has to be paid to the frequency regulation although it is not usual to incorporate specific protection against a low frequency condition. In diesel-alternator sets this is a direct function of the engine governor characteristics. The limits prescribed by BS.649 for engines used as prime movers for alternators are 10 per cent momentary and 4 per cent settled speed variations, on suddenly taking off or throwing on the rated load. By the use of a good governor and by maintaining the stationary engine at a reasonable temperature by means of an immersion heater it is possible to obtain a settled governing of 2 per cent with a 5 per cent momentary figure. With overspeed protection applied to the engine, either by the method mentioned earlier or by the design of the governor, high frequency faults, above for example 115 per cent of the nominal frequency, will be covered.

Low frequency conditions may be brought about by either an overload on the engine, or by failure of the engine to develop its rated output, due to wear or fuel injection trouble.

Delay operation circuits can be quite usefully employed when the conditions warrant. For instance, where the supply suffers from transient out-of-limits conditions, which do not justify the starting up of the standby set, a delayed starting circuit can be quite usefully employed.

A delayed stopping circuit can also be used to ensure that the mains are restored and attain stability for a given period, before transferring the load circuit back to the mains and stopping the diesel-alternator set.

On dual installations the delayed stop is a refinement which ensures that the outgoing set remains running for a short period after the incoming set has taken over. This will reduce the 'break' in the installation output if the incoming set proves faulty, and also eliminates the need for restarting the outgoing set, under this fault condition.

Cubicle indicator lamps indicate all operating or failure conditions. On a dual installation it is general practice to 'common' an indicator lamp to cover both sets. With the various alarm and operating conditions covered, it is general practice to provide one or two sets of spare contacts

for each alarm or operating condition. These contacts will be wired at the cubicle terminal board to separate terminals, from which points the remote indication circuits can be connected. Separate remote indication circuits can be employed, or the various alarms can be commoned into 'urgent' and 'non-urgent' groups.

5 SYSTEM RATING

The determination of the electrical load the installation has to supply is a simple matter, and involves

(i) The communications equipment load
(ii) Immersion heater units for the engine cooling systems
(iii) Battery charging load
(iv) Motor driven fan radiator (when used)
(v) Fuel transfer pump
(vi) Ancillaries, including lighting.

The engine rating will depend on the site conditions in accordance with well-known derating factors set out in BS.649/1949. From the manufacturers rated output from the diesel engine, based on a 12-hour rating, the following deductions are made:—

(i) Two per cent for each 10°F above 85°F of the maximum ambient temperature in which the engine is to operate.
(ii) Four per cent for each 1 000 feet above 500 feet above sea level at the engine site.
(iii) A certain percentage derating for relative humidity of atmosphere at the site maximum ambient temperature. The maximum derating under the worst conditions is not likely to exceed 6 per cent.

The above percentage deratings give the total percentage derating for site conditions based on the 12-hour rating. If the engine is to operate continuously, then a further 10 per cent derating on the site output has to be applied.

From the net continuous BHP rating at site the horsepower required for any ancillaries must be deducted before the final power available for the alternator drive is arrived at. Generally, this requires one deduction only, for the drive to the radiator fan of a water-cooled engine.

6 TRAILER SETS

When a project incorporates a large number of diesel-alternator sets, the additional expense of a mobile trailer unit is justifiable. If at the outset, trailer units are contemplated, this should be stated so that the control cubicles can be arranged for the reception of the trailer set controls.

Periodically, regardless of the operation of the installation, it is advisable to remove the diesel-alternator sets from service for complete overhaul. The trailer unit can be arranged to connect into the installation and perform the same automatic duties as the set which it is replacing, and in this manner the complete installation can be retained in full automatic operation.

7 CONCLUSIONS

The problems posed by the requirement for power units suited to long term operation have in general been solved. The equipment embodies basically standard units to which detailed attention has been given to provide the necessary long-wearing features.

This class of set is now giving satisfactory service in many parts of the world.

K. J. BLADON, born at Rednal near Birmingham in 1927, and educated at King's Norton Grammar School. He served an apprenticeship covering automatic power plant, following which he studied at Birmingham College of Technology. He was engaged on the design of power plant until 1951, during which period he also lectured at the Birmingham College of Technology. In 1951 he took a short service commission in the Education Branch of the Royal Air Force's Technical Training Command. On completion of his service he joined R. A. Lister and Company before taking up his present appointment on the technical staff of Pelapone Engines Limited.

On Channel Spacing . . .

OVER the past few years there has been considerable discussion both here and in the United States on the possibility of reduced separation between channels for mobile radio service in the VHF frequency band, culminating in the issue of new mandatory specifications for use in the United Kingdom. It is of general interest to examine some of the factors which affect the minimum spacing which can usefully be employed, since the introduction of new standards of operation is not without difficulty, particularly so far as owners of existing systems are concerned. It is important that users and manufacturers alike should feel sure that equipment which is produced should have a useful life before being rendered obsolete by changes in mandatory requirements.

At the outset a channel separation of 100 kc/s was standardized in Britain. This was in accord with international recommendations for the VHF aircraft and marine bands but was rather greater than the 60 kc/s current in the United States. Even so, there was little evidence of congestion as at that early stage systems were in the main confined to police and public utility services. Subsequently, as the use of VHF expanded, allocations of channels spaced at 50 kc/s were made in the 'low' band below 100 Mc/s by interleaving new allocations between the existing channels. This was accompanied by modifications to the specifications against which the equipment was type-approved, but this did not involve any great degree of difficulty as the specifications were not particularly rigorous.

Current U.K specifications are based on a concept of interference potential and set out to achieve predetermined standards of system performance which will enable more precise planning of frequency allocation, than was previously necessary. They involve very much higher standards of selectivity, stability and spurious radiation than were previously required, or considered possible economically. The new specifications call for channel separations of 50 kc/s as before but now apply to both the 80 and 160 Mc/s bands.

The ultimate reduction in channel spacing which can be achieved is limited by the fact that the modulation sidebands cannot be reduced below a certain minimum value. The acceptance bandwidth of the overall receiver is governed not only by this fact but also by the total permissible frequency tolerances of both transmitter and receiver comprising the communication circuit. This is shown in more detail in Fig.1. Once these limits have been determined the minimum channel separation can be established, from the viewpoint of receiver selectivity, in terms of the rate of attenuation outside the passband that can be achieved. A figure of 5-8 dB/kc/s can be achieved economically, which suggests that channel separations of 20-25 kc/s may prove usable from this viewpoint. The Table shows the characteristics which can typically be obtained by the use of lumped filter technique in conjunction with a double superheterodyne receiver.

Channel separation kc/s	100	50	25
Acceptance Bandwidth −6 dB	± 28	± 16	± 10
Bandwidth for 70 dB rejection	± 65	± 35	± 18

At the outset, frequency tolerances of ± 100 parts per million were permitted. The situation, particularly so far as the user was concerned, was then one of comparative ease. No special trimming of the oscillator crystals was involved and it could be expected that replacement of the valve or crystal could be carried out without adjustment, thus avoiding the use of high grade test equipment. Stabilities of ± 15 to 20 parts per million over the ambient temperature range 0° to 40°C are readily attainable once the manufacturing inaccuracies have been trimmed out, but this involves adjustment to the oscillator circuit every time any replacement or repair is made. It seems possible that stabilities of ± 10 parts per million are attainable without the use of thermostatic control, and

with this control this performance can be improved by a factor of from 3 to 5.

While thermostatic control is acceptable in fixed station equipment, it is to be preferred that conditions of operation should not require temperature control of the crystal oscillators of mobile equipment, since this introduces a further potential source of unreliability and also increases

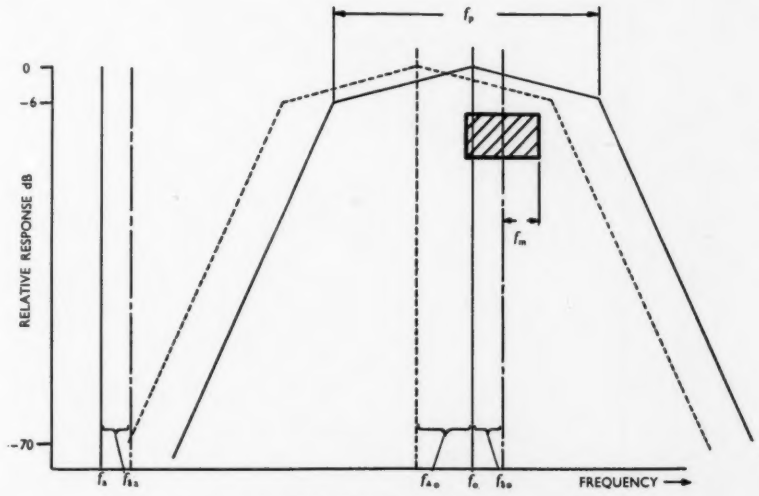


Fig.1. Factors determining channel spacing

fo = assigned channel nominal frequency.

fa = adjacent channel nominal frequency.

$f\delta a$ = maximum permissible positive excursion of adjacent channel transmission.

$f\delta o$ = maximum permissible positive excursion of wanted transmission.

$f\Delta o$ = maximum permissible negative excursion of receiver centre response (local oscillator plus IF errors).

fm = modulation envelope of wanted transmission.

fp = acceptance bandwidth at −6 dB.

The modulation envelope must be completely within the receiver passband when frequency errors are most unfavourable. Thus

$$\frac{fp}{2} = fm + f\delta o + f\Delta o, \text{ minimum}$$

The attenuation, A, provided against interference by an unwanted carrier is

$$A = [fs - (f\delta a + f\Delta o) - \frac{fp}{2}]\ R + 6\text{dB}$$

$$= [fs - (fm + 2f\delta o + 2f\Delta o)]\ R + 6\text{dB}$$

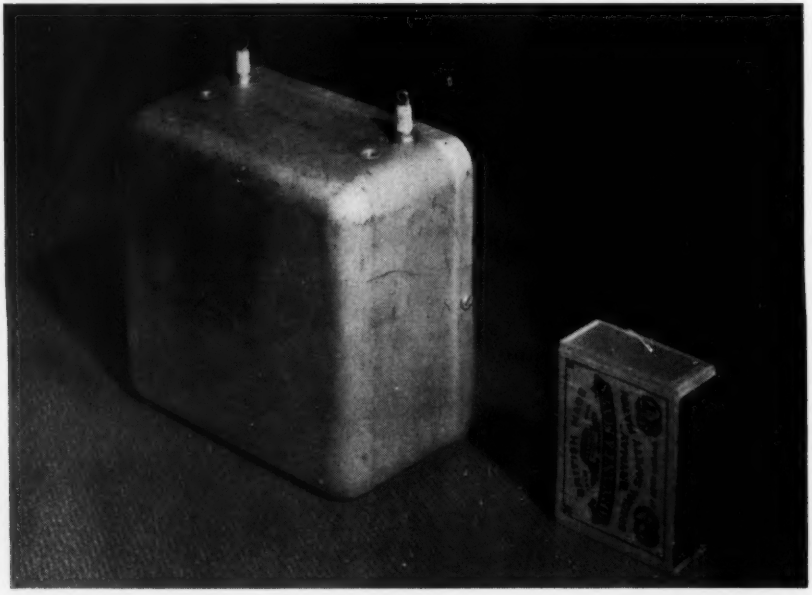
where fs = Channel separation

R = Mean rate of alteration outside the passband.

assuming $f\delta a = f\delta o$, a likely occurrence.

the power consumption. The mandatory requirements for the mobile equipments should permit the design of the simplest and most robust equipment which will meet the necessary performance requirements.

From the viewpoint of overall receiver selectivity there is little reason to suppose that channel separations of the order 20-25 kc/s should not



Lumped circuit IF Filter

prove practicable. However, other factors which affect system performance become increasingly difficult of solution. It should be borne in mind that the final selectivity is only obtained at a comparatively late stage and therefore the early stages of the receiver will amplify a large number of unwanted transmissions, some at high level. It appears probable that intermodulation and cross-modulation are going to be the limiting factors from this point of view, as this problem will become apparent under

the high density conditions of operation which are the chief justification for the adoption of minimum channel spacings.

Interference can be caused by the inability of a receiver to reject an unwanted transmission on a neighbouring channel. It can also be caused by spurious radiations from a transmitter operating on another channel falling within the acceptance bandwidth of the receiver. Modulation-limiting effects some improvement and is already common practice, but as the channel separation is reduced this problem becomes more acute and may involve the use of filters in the transmitter circuits. These filters are rather complex, as high rates of attenuation outside the passband are required. If located at high power levels in the transmitter, these filters can give rise to problems of temperature.

It can be seen, therefore, that it is readily possible to design and adjust an equipment to meet a stringent specification in the factory, where skilled technicians and adequate high grade test equipment is available. To maintain the performance in the field under the arduous conditions which are required of this type of equipment may be extremely difficult, and may make impossible demands on the maintenance facilities. There is no merit in the provision of a performance higher than is required if it is at the expense of reliable service and increased maintenance commitments, and therefore it is only where the maximum utilization of frequency spectrum is essential because the density of systems is high, that operation at the narrowest channel separation should be used. There is no merit in allocating channels on this basis elsewhere and it is in the interest of all parties to use high performance equipment of a kind which does not involve very precise adjustments, particularly of frequency, thus permitting that degree of latitude which will allow for long term trouble-free performance.

An Introduction to 'Rural Radio'

C. B. WOOSTER, M.B.E, A.M.I.E.E*

The application of radio in the realm of exchange-to-subscriber links has long been desired. It offers a means of providing telephone service to would-be subscribers remote from the local exchange where connection by landline is impracticable.

Although VHF single channel radio telephone equipment has been available for several years, the provision of a system which can be fully integrated with existing line telephone practice has not been easy. This article sets out the conditions to be met, and indicates how they can be provided in practice.

1 INTRODUCTION

THE AVAILABILITY of equipment operating in the VHF frequency band has made possible full integration of line telephone and radio networks using a straightforward hybrid transformer technique at the 4-wire to 2-wire conversion points. This integration is possible because the transmission medium for optical and quasi-optical paths is sufficiently constant to permit duplex circuits of high stability to be engineered using this simple conversion arrangement, and results in a performance comparable with good landline and cable circuits. While the stability of the medium is such as to permit the design of equipment carrying tens or hundreds of telephone channels over one radio circuit, the purpose of this article is to discuss simpler types of equipment where only one telephone channel is carried over an individual radio circuit.

This type of equipment facilitates the use of radio as an alternative to

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landline in the realm of exchange-to-subscriber links, and also for simpler junction circuits. It can thus provide a solution to what is frequently one of the most difficult problems facing a telephone administration, the provision of telephone facilities to an outlying subscriber where the cost of construction of a landline, even for party line services, would be prohibitively high. This application of VHF radio equipment to single channel telephone service has been given the generic title of 'Rural Radio'.

The success of a particular application derives in large measure from the unit which interconnects radio equipment of normal type into the established telephone system. This item, known as a signalling unit, can take various forms to suit the particular telephone system and therefore permits the use of standardized radio equipment.

2 SIGNALLING TECHNIQUES ON RADIO LINKS

For the effective introduction of a radio link into a telephone system it is necessary to simulate the equivalent landline signalling conditions without degrading them beyond acceptable limits. The basic signalling conditions required for both subscriber and manual junction links are shown in the Appendix. On the simpler classes of circuit required for these applications, only one of two possible conditions is to be indicated at one time; but for more complex forms of junction signalling, such as are involved on links between unit automatic exchanges and the parent exchange, a third condition has to be met. The particular signalling conditions in such a case are rather complex and are also dealt with in the Appendix.

Two methods of passing signals over a radio link can be used—carrier signalling and tone signalling. Keyed carrier signalling provides the simplest and cheapest method of control, and as the transmitters are only energized during calls, some economy in maintenance costs is achieved. It has become usual to use FM almost exclusively for this class of service, in view of the improved signal-to-noise ratios that can be obtained at low signal levels. However, the use of on/off carrier signalling with an FM system suffers from the disadvantage that a somewhat higher received level of carrier is required for positive signalling than is necessary for an adequate level of speech signal-to-noise ratio.

Aerial installation at Kuching 'Rural Radio' station

'Rural Radio' installation at Kuching, Sarawak

On long links with marginal signals, or where a high level of atmospheric noise or man-made interference might render a keyed-carrier system susceptible to false signalling conditions, a tone signalling system has advantages. In principle this uses a similar technique to that employed in multichannel carrier practice. Simple ring-down conditions can be provided with a tone of 500 c/s, modulated at 17 or 20 c/s to provide a guard against false voice operation. An outband tone of around 4 kc/s is also attractive, since it provides a means of passing a continuous supervisory tone whilst speaking, and can also be interrupted for dialling. On more complex systems, a 4-wire speech path can be extended to standard single or two frequency VF dialling relay sets, which can provide full trunk signalling facilities and incorporate terminating hybrid transformers. In this application, the VF dialling equipment is normally regarded as an integral part of the telephone exchange, and the radio link may be considered as forming a high grade 4-wire transmission path.

A third alternative is to use carrier signalling with frequency shift, which provides an additional signalling condition.

2.1 SIGNAL GENERATION AND DETECTION

It is not the intention in this article to delve too deeply into the technical aspects of a given range of equipment to meet the needs of a 'Rural Radio' service. Certain of the features that are required by the signalling systems involved are, however, different from those normally appertaining to simple VHF equipment and some mention of them will be of interest.

2.1.1 *Keyed Carrier Systems*

Signalling by means of carrier impulsing requires a substantially perfect transmitted waveform if incorrect operation of the telephone equipment is to be avoided. The transmitter supplies must either be well regulated, or the transmitter load absorbed during the keying intervals. However, the early stages must operate continuously, and therefore only the later stages of the transmitter are keyed. Precautions are necessary to ensure that the radiated output falls to a low level during 'space' periods.

In order to provide a signalling output from a receiver which is acceptably free from distortion, the squelch circuit on the FM receiver is ar-

ranged to operate the keying relay via a Schmitt trigger and DC amplifier circuit. Provision is normally made to control the sensitivity of the Schmitt circuit, and this gives reliable operation down to about a 3μV received signal.

2.1.2 *VF Tone Signalling*

In this case the transmitter radiates continuously and the signalling unit keys a tone oscillator. Suitable filter units are provided and a tone detector replaces the Schmitt trigger circuit in the receiver. Precautionary measures are necessary to prevent false operation.

2.1.3 *Signalling by Frequency Shift*

Frequency shift operation is an attractive variant of the keyed carrier system. It provides additional signalling conditions beyond the 'ON' and 'OFF' modes of keyed carrier and voice frequency systems, which are most valuable in the solution of the more complex signalling requirements such as UAX junction circuits. Thus, the 'ON' condition can be applied as:

(a) 'ON'—Normal
(b) 'ON'—Carrier high in frequency
(c) 'ON'—Carrier low in frequency

In principle, the technique entails changing the transmitter frequency by inserting series or parallel capacitors with the crystal, which is used at its anti-resonant frequency. A series capacitor will raise, and a shunt capacitor lower, the frequency. Detection of the frequency shift can take place at the receiver discriminator circuit.

Although the frequency shift system offers an elegant solution to several automatic exchange junction conditions, it is not altogether practicable for links involving repeaters.

The associated signalling unit will naturally be of the same order of complexity as the respective line circuit terminating relay set. Thus, a UAX radio junction termination now in service entails some 30 relays to effect the discriminating, timing and guard signals (compared with 36 relays on the associated UAX line junction relay set). By comparison, a simple subscriber's signalling unit only involves about 5 relays.

3 SIGNALLING UNITS

As we have already seen, the integrating element between a radio system of this type and the telephone exchange or subscriber is the signalling unit, which performs the following functions, illustrated in Fig.1 :

(a) Provides a 2 w/4 w hybrid transformer and balance, with suitable attenuators, for interconnection of transmitter, receiver and 2-wire line circuit at the correct levels for duplex operation.
(b) Provides relay circuits for converting the signals passed over the radio link to the appropriate 2-wire line signalling conditions.
(c) Provides direct current for energizing relays.
(d) Controls an inbuilt or external tone signalling system where applicable.
(e) Provides access test points for 2- and 4-wire circuits.

Signalling units for use with keyed-carrier systems can be designed for all types of subscriber and manual junction conditions, as well as for simple automatic junction circuits. Due to the inherently simple nature of this type of signalling, keyed carrier is much to be preferred where it can provide the necessary facilities and where the received signal strength is sufficient to provide fully reliable operation. However, the conception

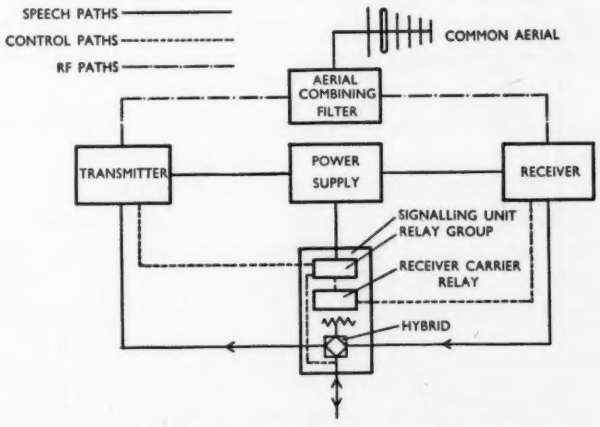


Fig.1. Schematic diagram of radio and signalling units

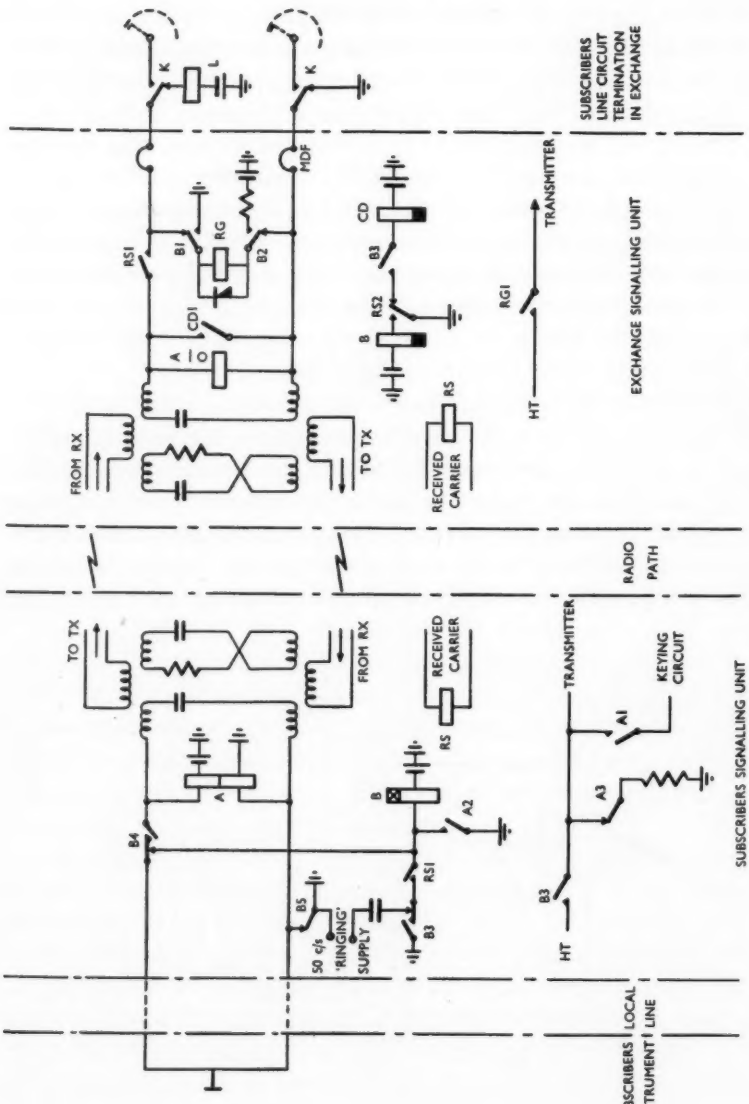


Fig. 2. Signalling arrangements for subscriber-to-exchange link

of the system is such that it is in the signalling unit itself that departures from standard practice can be made, and therefore a similar but more complex type of unit is employed where voice frequency signalling, out of band or carrier shift signalling systems are used.

4 SIGNALLING REQUIREMENTS FOR SUBSCRIBER LINKS

The principles set out above can perhaps best be illustrated by taking a particular case, and an exchange-to-subscriber link will be described. It is important that the signalling conditions should accurately conform with those existing in normal line practice, since so far as is practicable the operator should not be able to distinguish between a physical line and a radio circuit, from the operational point of view. The normal conditions that the radio, together with the signalling unit, will have to simulate will therefore be as follows:

(a) *Subscriber calls exchange*
The removal of the subscriber's handset (in the case of CB or auto exchange) disconnects the bell circuit and presents a loop to the exchange, which is interrupted during dialling. At the end of a call the loop is disconnected by replacing the handset.

(b) *Exchange calls subscriber*
17 c/s ringing current is extended from the exchange and operates the subscriber's bell. On answering, a loop replaces the bell circuit which trips the ringing at the exchange and gives a supervisory signal.

Fig.2 shows in schematic form the arrangements at each end of the radio path.

4.1 EXCHANGE SIGNALLING UNIT

This unit, illustrated in Fig.3, has alternative connections for CB/Auto or magneto terminations. It is intended for direct connection to a subscriber's line circuit, and gives normal subscriber conditions to any exchange. It is complementary to a subscriber's signalling unit.

4.1.1 *Signalling Conditions for CB/Auto Exchanges*

An incoming carrier operates the squelch relay RS (see Fig.2) which operates relay B, and then RG, switching on the local transmitter via

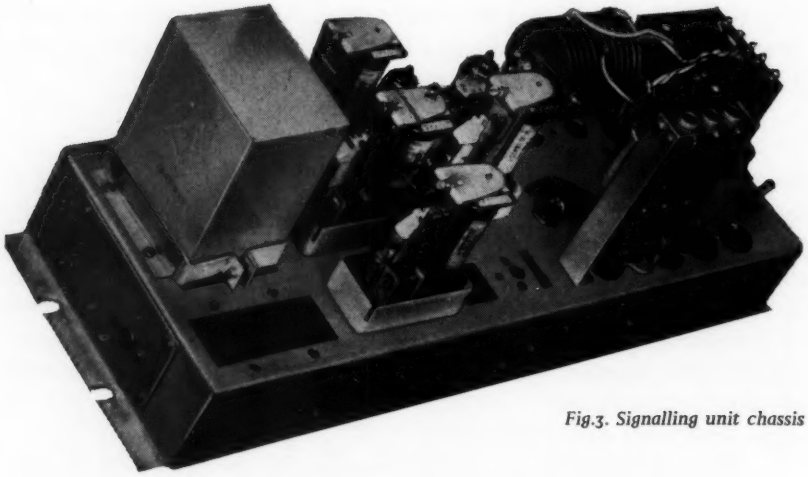


Fig.3. Signalling unit chassis

RG1, and completing the loop to the local exchange at RS1. At an automatic exchange, the RS relay pulses on receipt of interrupted carrier during dialling. The release of RS for the first time during impulsing operates CD. CD1 short circuits the impedance coil A, thus completing a non-inductive loop to the exchange during impulsing through RS1. Both relays B and CD are slugged for slow release, and therefore hold 'on' during dialling.

To call the subscriber, 17 c/s ringing from the exchange operates the RG relay, switching on the transmitter during ringing pulses. When the called party answers, RS operates to the returned carrier, completing a loop at RS1, which trips the ringing in the exchange and also operates the B relay. RG is then locked via B1 and B2, energizing the transmitter continuously (it will be noted that the exchange transmitter is under control of the called subscriber).

4.1.2 *Signalling Conditions for Magneto Exchange*

Alternative connections on the same signalling unit are employed as shown in Fig.4. No modification to the exchange is involved, but this

circuit is unsuitable for magneto junction working (since control of the exchange transmitter by the distant exchange is unacceptable for junctions).

On receipt of an incoming carrier at the exchange, relays RS, B and RG operate as before. The existence of a loop has no significance in a magneto exchange and it is therefore necessary for the subscriber to give a calling signal. This can take the form of an interruption to his carrier (e.g. by pressing a 'calling' button arranged to do this). This gives a pulse of 50 c/s 'ringing' to the exchange in the interval between the release of relay RS, and the slow release of the B relay, during which period relay CD is operated. When the distant transmitter is re-energized, RS again operates and restores the transmission path to the exchange.

The 'clearing' signal, a further pulse of 50 c/s 'ringing', is given automatically when the distant transmitter is closed down at the end of the call since the same sequence is repeated.

To call a subscriber, the operator applies ringing to operate RG. This switches the transmitter, and the subscriber's RS relay (operated by the received carrier) applies ringing to line, as in the CB/Auto case.

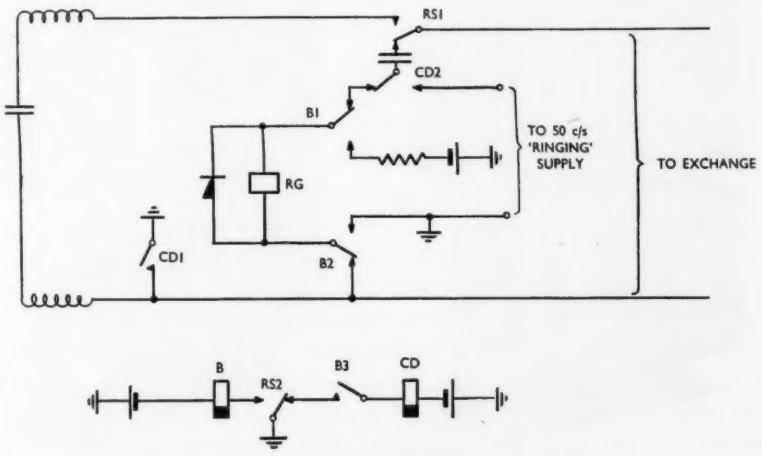


Fig.4. Signalling connections for magneto exchanges

Fig.5. Duplicate radio terminal equipment

4.2 SUBSCRIBER SIGNALLING UNIT

This unit, employed at a subscriber's termination, is complementary to the exchange signalling unit at a CB, Auto or Magneto exchange (Fig.2).

A calling subscriber loops the line, thus operating B and A relays, which together switch on the local transmitter, sending carrier to the exchange. On auto working the subscriber waits for dialling tone to be returned (the returned exchange carrier first operates RS). Dialling causes the A relay to pulse the transmitter via A1. During impulsing, B is held via B3 and RS1. On completion of a call, the A relay releases, switching off the transmitter. RS and B release when the exchange carrier is removed.

5 MAGNETO JUNCTION CIRCUITS

Special reference must be made to the problem of signalling over Magneto Junctions, since magneto exchanges are frequently employed in the areas in which 'Rural Radio' finds its principal applications.

The magneto system uses the same signalling conditions for both calling and clearing (i.e. a 17 c/s ringing current). Unfortunately, it is not possible to distinguish at a transmitter between a calling or clearing signal received from the line. This difficulty can be overcome by modifying the switchboard to give a loop to control the transmitter, and to maintain this loop for the duration of the call.

A preferable method, which avoids any modification to the switchboard, is to use 500/20 c/s signalling, or a tone outside the speech band, in conjunction with continuously radiated carrier. Some protection is provided against bursts of interference which could, in the absence of carrier, drop a magneto-type indicator, resulting in a false call.

6 RADIO EQUIPMENT

The effectiveness of a system of this type lies more with the signalling units than with the radio equipment, which can in fact be of any well-engineering type. Typical units illustrated in Fig.5, are compatible with the signalling unit and have been designed along the same general lines.

The transmitter, receiver, power supply, and signalling units are mounted on separate chassis. This equipment is operated from AC mains and is suitable for either exchange or subscriber operation, and has a

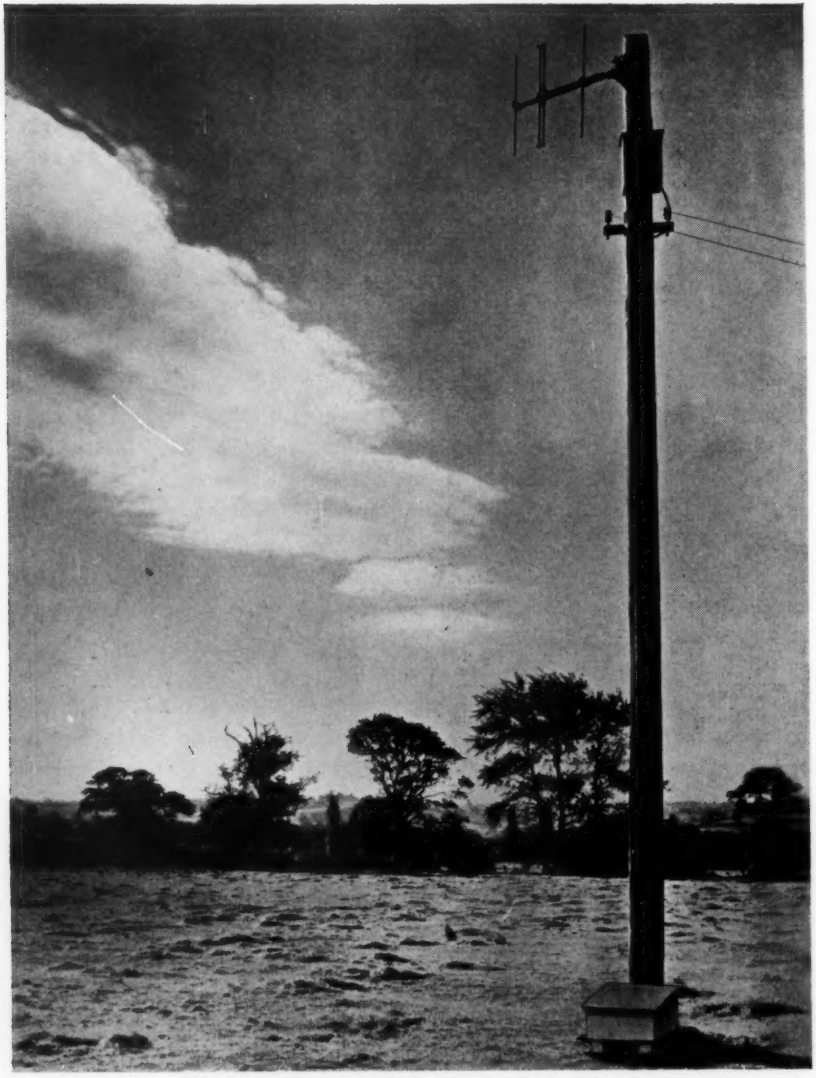


Fig.6. Low consumption subscribers' radio installation

performance such that, with carrier signalling, circuits over typical undulating country of 20 to 30 miles, or more when the siting at the terminals is favourable, are possible. Common aerial operation is possible by means of aerial diplexing filters. For this class of service, radio equipment is required to meet similar specifications to those of single channel VHF equipments in other fields, as the same qualities of frequency stability and ability to reject unwanted transmissions are required.

The earlier systems operated on AM, but while AM equipments are still available, they have been largely superseded by FM systems, which give greatly enhanced performance at signal levels which are normally experienced in this class of service. Transmitter output powers of some 10 watts in the frequency ranges 50-90 Mc/s and 156-184 Mc/s are normally adequate, while for long or difficult paths, 50 watt amplifiers driven by the output of the 10 watt transmitters can be used—an attractive feature of FM systems.

7 LOW CONSUMPTION SUBSCRIBER EQUIPMENT

One of the principal applications of a radio telephone system of this type is in sparsely developed areas, where individual subscribers are some distance from one another and the exchange. It is in such areas that a sufficient number of radio frequency allocations will be available to permit widespread utilization for subscriber-to-exchange operation. In such territories, availability of mains power supplies is generally restricted, so that while mains-operated equipment is tolerable for exchange operation, its use presents considerable problems so far as the ordinary subscriber is concerned. Not only is a suitable power plant, such as a diesel generator, necessary (which may well exist in many cases), but also the plant must run for the whole time during which a telephone service is required.

To meet this need many manufacturers have, over the past five or six years, devoted attention to the possibility of providing very economical radio equipments for use at the subscribers' end of the link. To be satisfactory a range of about 20 miles must be obtainable in conjunction with a mains-operated exchange terminal.

The use of transistors immediately comes to mind when contemplating a low-consumption receiver which can continually remain on watch for

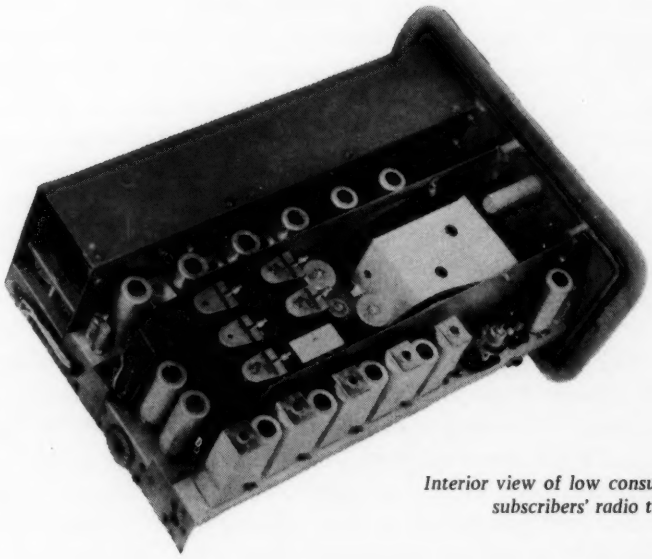
incoming calls. While these devices have made giant strides during the past few years it seems likely to be at least two or three years before transistors giving useful power gains at frequencies up to 200 Mc/s are going to be available, other than in the very smallest experimental quantities. Even at the time of writing, the variations over a production batch of transistors for use at comparatively low frequencies are very large. It therefore seems certain that a period of years must elapse before fully transistorized receivers in these frequency bands will be available, having sufficient reliability to be put into service at the isolated places called for in this type of application. A combination of valves and transistors is, of course, possible at the present time, but there seems little merit in the use of transistors *per se* if the requirement to use valves in the early stages calls for conventional vibrator HT and LT power supplies. So far as the transmitters are concerned, an even longer period seems likely to elapse before we may hope to get outputs of the necessary hundreds of milliwatts at these frequencies from transistors.

Alternative arrangements for conserving power supplies must therefore be considered. The requirements which such a set has to meet are:

(a) battery economy
(b) provision of standard operating conditions
(c) ease of installation
(d) the possibility of locating the equipment remotely from the subscriber, so as to derive the benefit of a good radio site, and therefore
(e) robust waterproof construction

Fig.6 illustrates a type of equipment which has been evolved to meet these conditions. It is produced as a self-contained, pole mounted, hermetically sealed unit and operates from a 12-volt battery. The 2-wire circuit is extended on a light spur route to the subscriber's premises. (The battery may be housed at the foot of the pole, as shown in Fig.6.)

Cyclic switching devices are used in these equipments operating the receiver, for example, for 3 seconds in every 30. With a typical receiver drain of approximately 1 amp during the listening-out period, a mean battery consumption of some 100 mA at 12 V is achievable. During the 3 seconds listening-out period, an incoming call can be received and locks the receiver to the carrier, sending ringing current to the subscriber. Out-



Interior view of low consumption subscribers' radio terminal

going calls can be originated at any time during the cyclic period. The transmitter only operates when the call is in progress, so the current consumption is of lesser significance. It is, typically, of the same order as the receiver for a power output of 500 mW. Under average conditions, therefore, a 100 AH 12 V battery will give service for approximately one month.

The signalling unit is generally similar to the normal subscriber's signalling unit, but includes ancillary contacts to control the cyclic switching circuit.

The problem of providing ringing current can be solved by applying vibrator output from the power unit to the telephone line. This ringing current is at a higher frequency than that normally used in telephone working, but is excellent in practice, if minor adjustments are made to the telephone bell. The use of a low frequency vibrator in the equipment (which would call for additional screening in the unit) can thus be avoided.

8 USE OF REPEATERS

The routes over which single channel circuits operate sometimes require an intermediate repeater. This can take the form of standard equipment connected back-to-back. For keyed carrier systems, the audio speech path is extended 4-wire through suitable attenuator networks, whilst the keyed carrier signals operate the complementary transmitter. When voice frequency or outband tone signalling is used, the repeater-transmitters are permanently operated, and the carrier controlled circuits are available for systems-alarm functions.

9 SUBSCRIBER GROUP WORKING

Some administrations find that the cost of provision of an individual link per subscriber is uneconomic, as they may be obliged for various reasons to limit rentals according to an arbitrary scale. A significant saving in the unit cost of a subscriber's radio link can be made by sharing the exchange-end apparatus between several subscribers. This is attractive for links with a low calling rate and, in fact, corresponds to the use of common equipment in telephone exchanges. Any such arrangement should conform to the following conditions:

1 Privacy.
2 Identification of subscribers at the exchange.
3 Intercommunication, via the exchange, between subscribers on the same network.
4 Use of standard exchange equipment.
5 Use of standard radio link terminal equipment, with suitable switching and control units.
6 Forced release of long-duration calls.

Two methods of approach may be made to this problem:

(a) To allocate separate frequency channels to each subscriber and arrange for the exchange equipment to hunt over a group of channels.
(b) To use one or two radio channels for the whole group and apply selective calling to each subscriber.

With either method of working, the same basic principles determine the practical arrangement of a group of subscribers. Thus, a group of 6 to 10

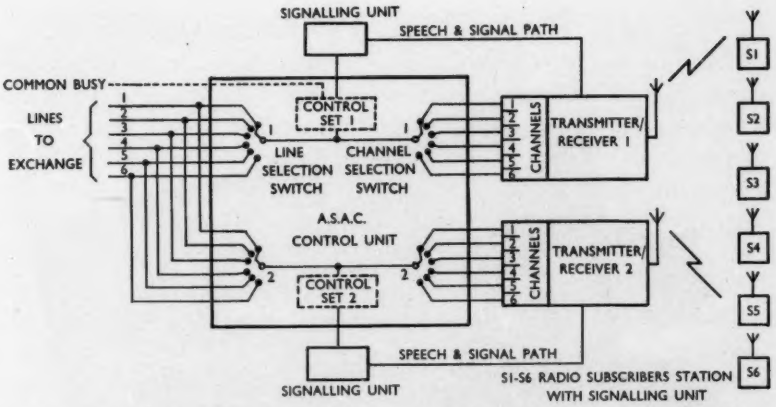


Fig.7. Schematic arrangement of a 6-circuit channel-sharing ASAC termination

subscribers can be served by one set of exchange equipment. However, the exchange end must have a minimum of two transmitters and receivers, to permit interconnection between subscribers on the system.

9.1 A SWITCHED FREQUENCY SYSTEM

An example of the 'channel-per-subscriber' arrangement is the ASAC (Automatic Selection of any Channel) system. This system employs standard equipment at outstations, either mains or battery operated, and is engineered for groups of six subscribers with two exchange terminals. The terminal transmitters and receivers are fitted with crystals and channel switching relays for six adjacent channels. A block schematic of the central station is shown in Fig.7. The unit itself is shown in Fig.8.

An attraction of such a system is the absence of auxiliary equipment at outstations. Subscriber identification is achieved simply by channel switching at the exchange.

To avoid blocking the network by calls of long duration, or fault conditions, a forced-release facility is necessary, and a simple timing device can be arranged to disconnect a call after a suitable warning signal has been given.

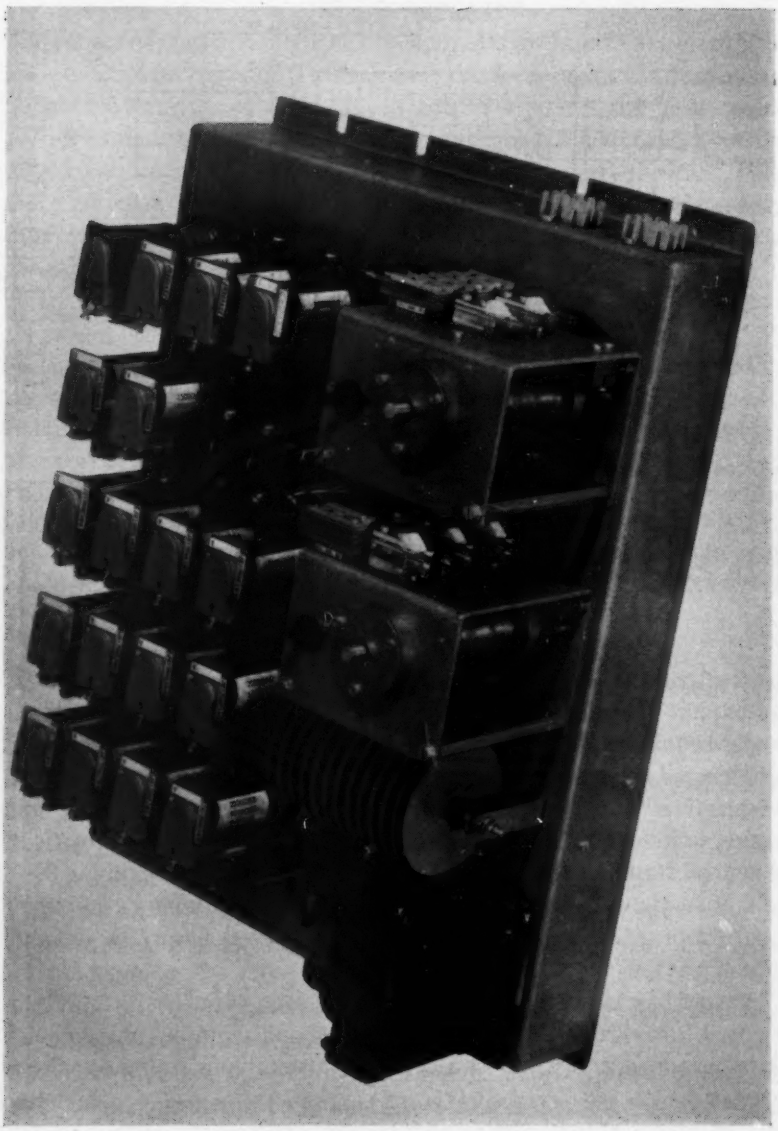


Fig.8 ASAC six-station control unit

9.2 SELECTIVE CALLING SYSTEMS

A more economical use of frequencies is achieved with selective calling systems, but the outstation equipment is more complex. Besides having means for detecting and generating the selective calling signals, provision must also be made for channel switching to meet the requirement for two outstations to inter-communicate via the exchange. Selective calling over a radio system may be by impulses or tones; tones are preferred as they are less susceptible to false operation by static, or carriers from other stations on, or interfering with, the network. A tone calling system must, however, be immune from voice operation and it must be simple to set up the units on any selected tones so that outstation apparatus can be exchanged for maintenance purposes. Such a tone-operated system should, if possible, be fully compatible with existing telephone practice, and positive identification is also a problem difficult of solution.

10 CONCLUSION

The full integration of single channel VHF radio links with line telephone systems is possible using the techniques discussed in this article, and enables communication to be opened up in areas where the erection of landlines would be impracticable. The equipment is relatively simple and does not impose undue maintenance problems on Administrations; alternative signalling units provide a wide range of signalling facilities.

The applications of 'Rural Radio' are already diverse, ranging from single links with lighthouses to national junction networks. The system admits of development and will permit the incorpation of advances in radio and signalling techniques, thus leading to more widespread applications.

Appendix

IN SECTION 2 the signalling requirements of a telephone circuit as they affect radio links were discussed in general terms.

One of the major problems in the development of a radio system, which is to be fully compatible with the various types of telephone system at present in operation, is the wide range of signalling conditions used. For the simpler cases, only one of two signalling conditions has to be transmitted at a time. This can be readily provided by simple variants of a standard keyed-carrier system.

The requirements of various systems are set out in Table I.

If the signalling units provide accurate conversion from the form of signalling which can be passed over radio to the circuit conditions required by the telephone system, the system, or an operator, is unable to tell whether a line circuit or radio circuit is in

Table I: *LINE CONDITIONS*

Type of Circuit	*No Call*	*Outgoing Call*
Sub to Exchange. Subscriber's Termination. (a) CB or Auto.	Bell across line in series with condenser.	DC loop across line through microphone interrupted during dialling.
(b) Magneto.	Bell across line as above.	17c/s ringing to line.
Sub to Exchange. Exchange Termination. (a) CB or Auto.	Battery and earth to line through relays.	17c/s ringing to line.
(b) Magneto.	Calling Indicator across line.	17c/s ringing to line.
Magneto Junction.	Calling Indicator across line.	17c/s ringing to line.
CB Junction.	Earthed relay on B line.	Battery via relay on B line, earthed supervisory relay on A line.
Auto-Auto Junction (between automatic exchanges).	Battery and earth fed to line via relays meeting conditions of like polarity from distant exch.	Line looped with low impedance shunt-field relay, with battery and earth fed from a high impedance relay. Loop interrupted during impulsing.

use. It is of course necessary to ensure that the radio circuit will not degrade signalling conditions beyond those which can be accepted by the remote telephone equipment. This is particularly a requirement in the case of a dialling system where the nature of the received dialled impulses is of some importance.

The requirements to be met by radio links when used in conjunction with automatic systems can become somewhat complex in the more elaborate cases. The requirements particularly of junctions connecting unit automatic exchanges to their parent exchange require a number of signalling conditions for metering and discriminating purposes which are provided by, among other methods, reversal of battery polarity on one of both lines of the telephone pair. There is no direct parallel for the radio circuit of a battery reversal but the use of carrier frequency shift or VF tone modulation can increase the facilities which can be provided by a keyed carrier system. These applications are, however, rather specialized (as can be seen from Table II) and it is usual to treat each as an individual case.

Signalling Condition on Subscriber and junction links

Incoming Call	*Speaking*	*Clearing*
17 c/s ringing operates bell. Ring tripped by answering loop.	Loop maintained by telephone across line.	Loop disconnected. Bell and condenser across line.
17 c/s ringing operates bell.	Telephone across line.	17 c/s ring to line.
Relay operated by subscriber's loop on line.	Supervisory or control relays operated by line loop.	Disconnection of loop releases relays. Selectors restore or 'clearing' supervisory signal given on switchboard.
17 c/s ring from line operates calling indicator.	Cord circuit supervisory indicator across line.	Supervisory Indicator operated by 17 c/s 'ring off' from sub.
17 c/s ring from line operates calling indicator.	Cord circuit supervisory indicator across line.	Supervisory Indicator operated by 17 c/s 'ring off' from line.
Battery from B line operates calling relay.	Battery on each line.	Calling or responding battery removed from line.
Received loop operates incoming selector, which steps to interruption of loop.	When called party replies, battery and earth reversal returned from Final Selector, operating shunt field relay in O/G relay set at distant station giving supervisory and metering conditions.	Clear by called party restores shunt field relay. Clear by calling party releases whole connection.

Table II: *JUNCTION CONDITIONS*

Signalling Conditions at Auto-Manual Parent Exchange on bothway junctions to UAX

Type of Call	*Operating Condition*	*Signalling Condition*
Normal or quiescent state.		Battery and earth via relays to −ve and +ve lines respectively meeting similar conditions from UAX.
Incoming call to auto equipment (i.e. Level '9' from UAX subscribers to dial numbers directly into main auto exchange).	Calling condition.	Loop from line, interrupted during dialling.
	Called party being rung, normal.	Battery and earth to −ve and +ve lines.
	Called party engaged.	Busy flash returned to line (i.e. alternate pulses of (a) battery and earth plus busy tone and (b) battery to both lines).
	Called party answers.	Reversal of battery and earth to +ve and −ve lines (to control metering at UAX).
	Called party clears.	Restoration of battery and earth to −ve and +ve lines.
	Caller clears.	Removal of loop from UAX restores auto equipment to normal.
Incoming call to manual board (ordinary) (i.e. UAX. Subscriber dials 'O').	Calling condition.	Battery received on +ve line operates 'ordinary' calling lamp.
	Caller clears or flashes.	Substitution of battery by earth on +ve line from UAX operates supervisory lamp.
	Manual hold condition when caller clears.	On removal of calling battery from +ve line, battery is returned from manual board on +ve line to UAX giving the operator control of the junction and 'holding' the caller.
	Operator re-rings caller.	The 'manual hold' battery is replaced by positive battery on +ve line during ringing.

Type of Call	*Operating Condition*	*Signalling Condition*
Incoming call to manual board (coin box) (i.e. call office dials 'O' from UAX).	Calling condition.	Earth received on −ve line operates 'Coin Box' (Red) calling lamp.
	Supervisory, manual hold and re-ring.	As for Ordinary Subscribers 'O' level call.
Manual board or operator controlled call outgoing to UAX.	Operator dials out.	Loop on junction seizes selector at UAX. Interruption of loop during dialling.
	Called party answers.	Battery and earth reversal from −ve and +ve to +ve and −ve lines from UAX, controlling supervisory at exchange.
	Called party clears.	Restoration of battery and earth to −ve and +ve lines from UAX.
	Called party busy—trunk offering.	Busy tone and flash received from UAX. Operator applies earth to one leg of junction to operate a differential relay in final selector and extend a speech path to the engaged called party.
	Operator re-rings a cleared called party (as distinct from trunk offering an engaged line).	Earth extended on one leg to to operate differential relay.
Outgoing call from parent exchange selector levels to UAX (i.e. a parent exchange subscriber dials a number on the UAX).	Calling condition.	Loop to line seizes UAX selectors, loop interrupted during dialling.
	Called party answers.	Battery and earth reversal from line operates caller's meter.
	Called party busy.	Busy tone and flash returned from UAX.
	Called party clears after talking.	Restoration of battery and earth to −ve and +ve lines at UAX.
	Caller clears.	Restoration of junction to normal.

1. The conventional exchange battery is −50 volts to earth, but for certain discriminatory signals an alternative 'Positive Battery', +50 volts to earth is employed.
2. The −ve and +ve lines are conventional designations of the two line wires.
3. Discriminating Signals are given from the UAX for 'dialling in', and Ordinary or Call Box 'O' level operator calls.
4. Multimetering and trunk barring facilities on outgoing calls from a UAX are controlled by auxiliary equipment in the UAX and do not involve additional junction signalling facilities.

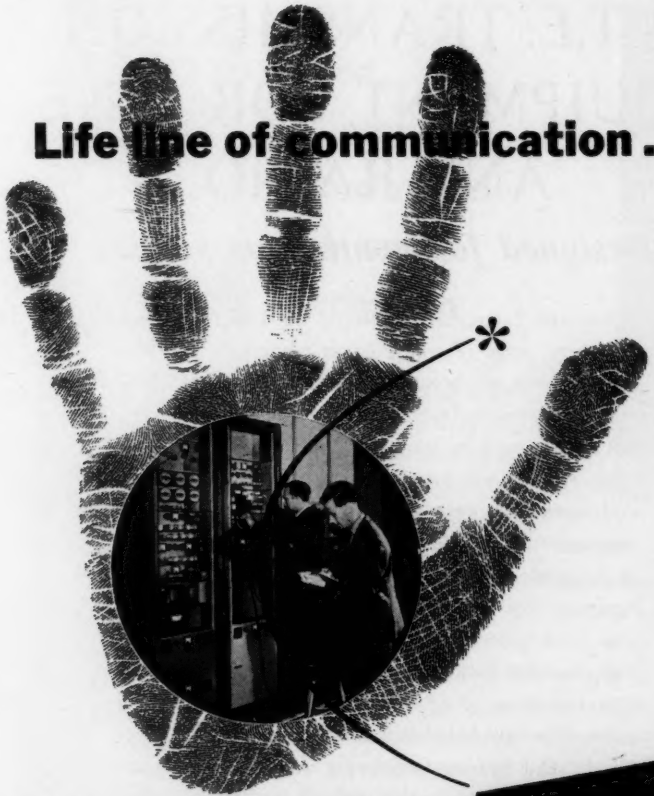
C. B. WOOSTER, born in 1917 in Chelmsford where he was educated at King Edward VI School. In 1935 joined Post Office Engineering Department, and was engaged on automatic and manual exchange planning and installation.

Served in Royal Signals during the war, mainly in technical staff appointments overseas responsible for long lines and fixed radio systems. Seconded for a short period to Sudan P & T Department.

At the war's end he returned to the G.P.O. In 1948 he left to join the Kuwait Oil Co. to plan their communications network. In 1950 he became a member of the Radio and Transmission Division of the Automatic Telephone & Electric Co. Ltd., where he has been in charge of the Sales Engineering Group responsible for single and multichannel VHF systems, and was intimately concerned with line and radio integration developments. Since July 1956 he has been in the A.T.E Home Sales organization and is primarily concerned with major transmission systems and carrier equipment for use on radio systems.

Designed by London Typographical Designers Limited. This journal is set in 8 pt and 12 pt Linotype Pilgrim and is printed in Great Britain on Bowater's Lithocote SM2 by The Shenval Press, London, Hertford and Harlow.

Life line of communication . . .



World wide radio-communication began with Marconi's Transatlantic messages in 1901. Since then Marconi research and development have led to every major advance in technique. Marconi equipment today, operating at all frequencies, covers a very wide field of both long and short range radio-telegraph and radio-telephone requirements. Marconi Multi-Channel Equipment can provide up to 600 telephone Channels and is largely superseding land-line or cable routes on grounds of efficiency, economy and, where terrain is difficult, ease of installation and maintenance.

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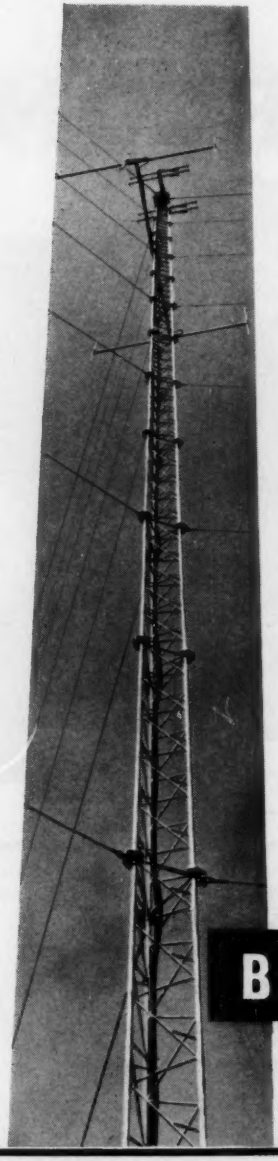

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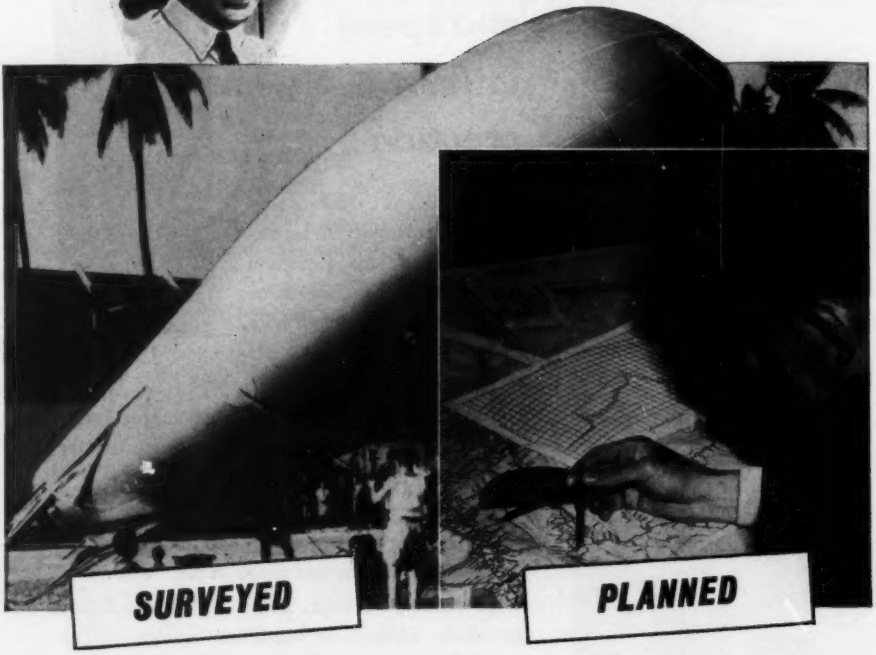

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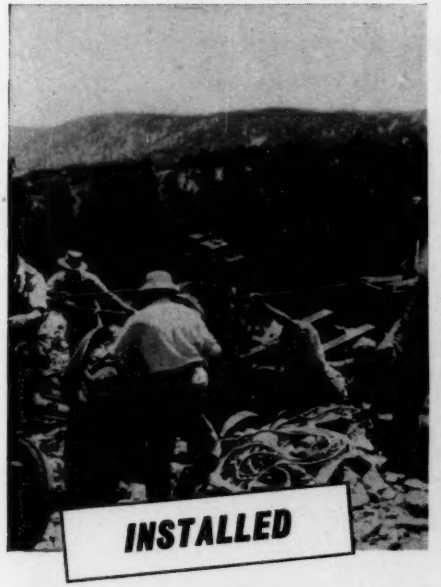

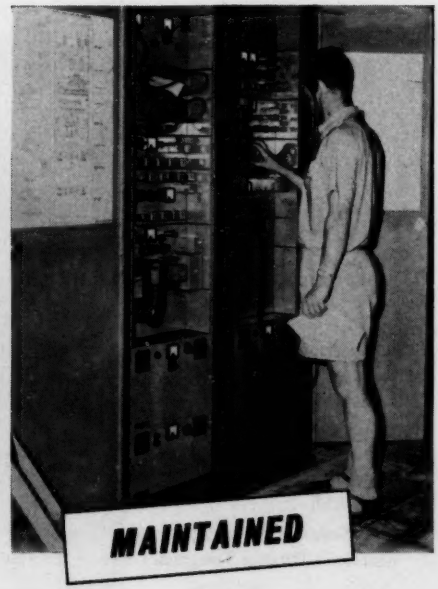

MARCONI'S & A.T.E. Co-operation between Marconi's, and Automatic Telephone and Electric Co. Ltd., now brings together an unrivalled wealth of knowledge and experience for the benefit of all whose work lies in the field of telecommunications.

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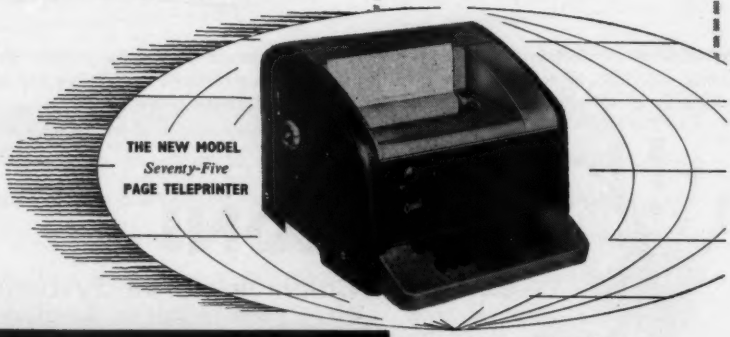

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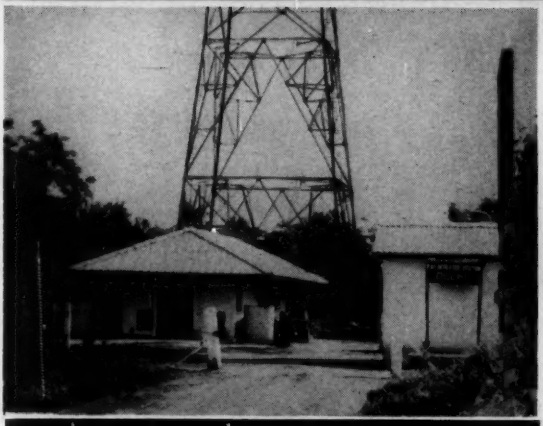

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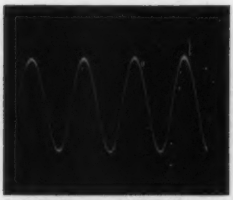
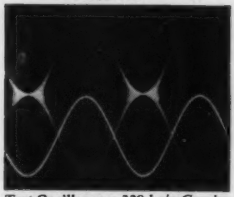


Test Oscillogram 15 Kc/s Unmodulated Carrier showing good waveform.



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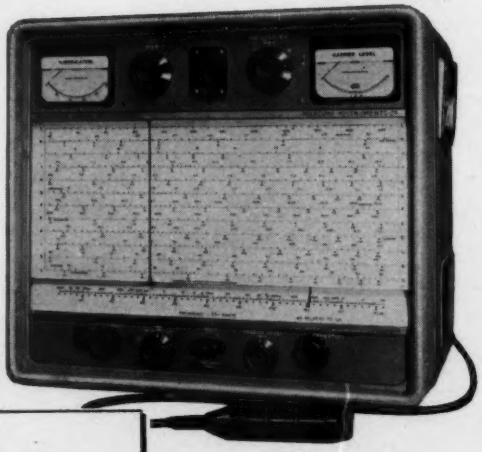

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